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BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPER IN THIS NUMBER.

"Highway Construction in Massachusetts." Arthur W. Dean.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

MINUTES OF MEETINGS.

BOSTON, December 21, 1921.

The regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, and was called to order at 8 o'clock by the first Vice-President, Frank M. Gunby.

There were 116 members and guests present.

The minutes of the meeting of November 16 were read and approved.

The Chairman announced that the Board of Government had elected the following to membership in the grades named:

Members — Messrs. A. O. Bradshaw, E. S. Clark, H. F. Heald and K. F. Jackson.

Juniors — Messrs. G. D. Ballou, P. E. Bodemer, F. W. Chase, Jr., L. H. Chouinard, H. H. Crossman, R. B. Ely, A. E. Everett, Jr., C. J. Ginder, E. R. Harlow, Jr., H. H. Jones, H. D. Johnson, Jr., F. E. Junior, H. W. Kelly, A. E. Kendrew, W. H. Law, C. G. Leavitt, Maurice Marcus, C. A. May, J. J. Meagher, E. M. Norberg, E. S. Parsons, W. M. Parsons, E. J. Pinkul,

C. T. Rhoades, Benjamin Rubin, J. C. Rundlett, J. B. Russell, A. L. Savignac, W. Semenyna, E. O. Stearns, C. S. Toole and G. D. Vincent.

The Secretary announced that, under authority of the Board of Government, the President had consummated the formation of the Section to be known as the "Northeastern College Section" of the Society.

The Secretary read a letter from the President welcoming the members of the Engineering Society of the Northeastern College as a section of the Boston Society of Civil Engineers.

The Chairman announced the death of William E. Baker, who died November 7, 1921, and was authorized to appoint a committee to prepare a memoir.

The Chairman then introduced the speaker of the evening, Mr. A. W. Dean, chief engineer, Division of Highways of the Public Works Department, Commonwealth of Massachusetts, who read a paper entitled "Highway Construction in Massachusetts." Mr. John R. Rablin, chief engineer, Park Division, Metropolitan District Commission, opened the discussion by presenting the practices of that department. The papers were then discussed by the following: Messrs. Macksey, Porter, Doris, Rowe, Larned, Metcalf, Rice and Hodgdon.

Adjourned.

RICHARD K. HALE, *Acting Secretary.*

BOSTON, December 28, 1921. — A special meeting of the Boston Society of Civil Engineers was held this evening in the rooms of the Society in Tremont Temple, and was called to order at 8 o'clock by the Second Vice-President, Edwin H. Rogers.

There were 55 members and guests present.

The purpose of the meeting was for the discussion of tentative specifications for concrete and reinforced concrete prepared by a joint committee from the following societies: American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering Association, Portland Cement Association and American Concrete Institute. This report was submitted to the constituent organizations on June 4, 1921, and has been published in various journals and periodicals.

Mr. Leonard C. Wason opened the discussion and announced that the record of the meeting would be submitted to Professor Voss of Wentworth Institute, who has kindly consented to digest and edit the notes for the presentation to the joint committee.

The paper was then discussed by the following: Messrs. L. J. Towne, E. S. Larned, A. C. Tozzer, B. F. Guppy, H. F. Bryant, C. M. Spofford, W. C. Voss, C. E. Nichols, E. F. Albright, Rice, Ramsey, Alvord, Woodruff and H. A. Varney.
Adjourned.

RICHARD K. HALE, *Acting Secretary*.

BOSTON, December 7, 1921. — A regular meeting of the Sanitary Section of the Boston Society of Civil Engineers was held this evening in the Society rooms, Tremont Temple. The meeting was called to order at 7.50 P.M., by the Chairman, H. K. Barrows.

The records of the October meeting were read and approved.

The Chairman announced that the Executive Committee had elected to membership Messrs. J. Henry Duffy and Scott Keith.

The Chairman then introduced the speaker of the evening, Mr. Ralph W. Loud, assistant engineer, Sewerage Division, Metropolitan District Commission, who spoke on the Metropolitan Sewerage Works.

The subject was discussed by Messrs. Lamson, Stiff, Eddy and Marston.

Meeting adjourned at 10 P.M.

Members present, 41.

JOHN P. WENTWORTH, *Clerk*.

BOSTON, December 14, 1921. — The regular December meeting of the Designers Section of the Boston Society of Civil Engineers was called to order at 6.10 P.M. by the Chairman, Ralph E. Rice.

There were 42 members and guests present.

The minutes of the two preceding meetings were read and accepted.

Past President George F. Swain was introduced and gave an intensely interesting and instructive talk on earth pressure. The paper was then discussed by Messrs. F. A. Marston, C. B. Breed, L. F. Cutter and others, who brought out additional points of interest and value.

Meeting adjourned at 7.40 P.M.

A. L. SHAW, *Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[January 15, 1922.]

The By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

FOWLER, WILLIAM H., Melrose, Mass. (Age 26, b. Needham, Mass.) Graduate of Lynn High School in 1914, and entered Mass. Inst. of Technology in September of that year, but, on account of ill health, left in February of 1916, to go on a country farm. In the fall of 1916 worked with Whitman & Howard, surveying and drafting; with Richardson & Hale from Nov., 1916, to Feb., 1917; with George W. Cutting, Jr., Feb. 5 to Apr. 24; and division engineer with the B. & M. R. R., Apr. 25 to June 28; enlisted in U. S. N. R. F. and served from Oct., 1917, to Jan., 1919; with the Boston Rubber Shoe Co. from Jan., 1919, until fall of that year; entered Northeastern College in the fall of 1919, and during the work periods was with Monks & Johnson as a draftsman, with the exception of five weeks with Turner Construction Co., on line and grade work; with the Highway Commission from June 1 to Oct. 22

on bridge construction. At present is attending Northeastern College. Refers to H. B. Alvord, G. W. Cutting, Jr., C. S. Ell, J. J. Harty, Jr.

INGALLS, JAMES W., Lynn, Mass. (Age 35, b. Lynn, Mass.) Graduate of Dartmouth College in 1910 with B.S. degree, also a graduate of Thayer School of Civil Engineering in 1911 with a C.E. degree, having completed the two-year course. From May to Sept., 1910, and May to June, 1911, assistant to the city engineer of Barre, Vt., on city work; also transitman on construction of a water-supply reservoir; June to Nov., 1911, junior topographer with the U. S. Geological Survey at Montpelier, Ida.; Nov., 1911, to May, 1912, draftsman with J. P. Snow on railroad and highway, timber and steel bridges; May to Dec., 1912, instrumentman on the N. E. R. R. at Brimfield, Mass., on construction work; Jan. to Apr., 1913, track supervisor at Central Aquirre, P. R.; June, 1913, to June, 1919, with the engineering department of the Maine Central R. R., as transitman, then assistant engineer, then resident engineer; June, 1919, to Aug., 1921, treasurer and general manager of the J. F. Ingalls, Inc., Lynn, Mass. At present president of J. F. Ingalls, Inc., not actively in business; since Sept., 1921, instructor in civil engineering at Northeastern College. Refers to H. B. Alvord, C. S. Ell, R. E. Parker, J. P. Snow, B. T. Wheeler and H. C. Whittemore.

LIST OF MEMBERS.

ADDITIONS.

BRASK, HENRY	23 12th St., Attleboro, Mass.
COOK, HAROLD S.	88 Auckland St., Dorchester, Mass.
COOPER, CHARLES S.	4 Perth St., Dorchester, Mass.
CUNDARI, JOSEPH V.	756 Third St., South Boston, Mass.
HARDING, ARTHUR E.	111 Gainsboro St., Boston, Mass.
HEALD, HAROLD F.	171 Powder House Blvd., Somerville, Mass.
HOAR, WILLIAM V. P.	1061 Dorchester Ave., Dorchester, Mass.
MILNE, DAVID C.	188 Washington St., Dorchester, Mass.
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WILLIAMS, EDWIN C.	15 Harvard St., Natick, Mass.

CHANGES OF ADDRESS.

BIGELOW, LYMAN W., Care United Fruit Co., Engrg. Div., Puerto Barrios, Guatamala, C. A. Via New Orleans.	
BURRAGE, HENRY T., Care Capt. A. W. Burton, Fort Moultnè, Charleston, S. C.	
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HORNE, HAROLD W.	603 Belmont St., Belmont, Mass.
SAVAGE, J. DANA.	334 Malden St., Medford, Mass.
SNOW, BENJAMIN H.	28 Lebanon St., Winchester, Mass.
STEARNS, RALPH H.	Room 306, Hall of Records, New York, N. Y.
TURNER, HOWARD M.	120 Tremont St., Boston, Mass.

LIBRARY NOTES.**RECENT ADDITIONS TO THE LIBRARY.****U. S. Government Reports.**

- Activities of the Bureau of Yards and Docks. 1917-18.
Librarian of Congress, Report of. 1921.
Superpower Survey Report. W. S. Murray and others. 1921.
Wood-using Industries of New York. U. S. Department of
Agriculture.
United States Coast and Geodetic Survey. 1921.

State Reports.

- Massachusetts. Annual Report Highway Commission.
1910-1911.
Massachusetts. Annual Report Metropolitan District
Commission. 1920.
Rhode Island. Annual Report Public Utilities Commission.
1920.

City and Town Reports.

- Melrose, Mass. Annual Report Public Works Department.
1920.
New Orleans, La. Semi-Annual Report Sewerage and
Water Board. 1920.
New York, N. Y. Contracts 209, 210, 211, Board of Water
Supply. 1921.
Philadelphia, Pa. Annual Report Bureau of Surveys. 1919-
1920.

Miscellaneous.

- Practical Least Squares. Ora Miner Leland. Gift of
publisher.
Proceedings of A. S. T. M. 1921. Gift of L. C. Wason.

LIBRARY COMMITTEE.

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PAPERS AND DISCUSSIONS

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HIGHWAY CONSTRUCTION IN MASSACHUSETTS.

BY ARTHUR W. DEAN,* MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented December 21, 1921.)

THIRTY years ago there was an extensive propaganda for better roads, due at that time to the desires of the manufacturer and of the user of bicycles, the one to increase his sales, and the other to increase his enjoyment. To-day the propaganda is by the manufacturer and user of motor vehicles, one for the same reason that formerly inspired the bicycle manufacturer, and the other for far greater reasons, in that where the bicycle was used almost wholly for pleasure the motor vehicle is not only used for pleasure but is one of the prime commercial requisites of the present day.

The first states to be effectively influenced by the bicycle propaganda were Massachusetts, Connecticut and New Jersey. The first legislation in Massachusetts leading toward state activities in road construction was in 1892, when the legislature passed an Act which did not authorize any construction, but provided for investigation and recommendation by a Commission. Ten thousand dollars was made available for this purpose. The first real constructive Act was in 1894, in which year the state appropriated \$300 000. This, at the time, was considered by many as an extravagance on the part of the state,

*Chief Engineer, Division of Highways, Public Works Department, State House, Boston, Mass.

and little did they foresee at that time that in 1921 there would be state funds available in the Commonwealth for highway expenditure amounting to very nearly \$8 000 000.

The rapid increase in the appropriations and in the progress in road building under state supervision may be attributed almost wholly to the motor vehicle, and a few statistics are here given in order to show the necessity for the expenditures of large sums of money in the improvement of the highways.

Motor vehicles first became sufficiently numerous to require regulation and registration in the year 1907, and in the following year motor vehicles were first registered in Massachusetts. Very few of the states at that time required registration, hence statistics as to the number of motor vehicles using the highways in the United States that year are not available. In 1920, according to a table prepared by the Bureau of Public Roads in Washington, there were approximately 9 000 000 cars registered in the United States, that being 83 per cent. of all motor cars in the world. This number of cars indicates one car for each 11 persons in the United States, or 3.8 cars for each mile of highway. In the same year, 1920, there were registered in Massachusetts 274 498 motor vehicles, being one vehicle for each 11 persons and 12 vehicles for each mile of public way.

There is, at the present time, strong agitation by those interested in securing funds for highway construction and maintenance, to place upon the owners and users of motor vehicles a greater responsibility or liability for payment of the expense of construction and maintenance of our highways. By some people the principal advocates of increased registration fees are considered as carrying on the agitation for political rather than business reasons, but the above figures should indicate that funds must be secured from some source, the possible available sources being (1) direct taxation, (2) bond issue, (3) fees from users of motor vehicles.

If the state is to progress in its road-building program one or all of the above sources must be utilized, and as the users of the motor vehicles derive the immediate benefit, it is quite natural and fair that the users should bear their fair portion of the road expense.

Massachusetts began raising funds by the issuance of thirty-year bonds. This policy was pursued until the year 1913, in which year, and for four succeeding years, fifteen-year serial bonds were issued. Beginning in 1919, however, the Commonwealth ceased issuing bonds for highway purposes, and money was raised from ordinary revenue.

The total amount of bonds issued by the Commonwealth to November 30, 1921, for state highways and "small town" construction was \$11 767 000. The amount outstanding on the above date was \$6 745 500. A sinking fund, however, established when the bonds were issued, brings the net debt down to about \$3 000 000.

The change in the type of vehicles using the road has been followed in natural sequence by the necessity for change in the type of construction. The original adopted types of state highway were the water-bound macadam for the principal roads and gravel for secondary roads.

About 1907 it became evident that the water-bound macadam road or the gravel road would not withstand motor vehicle traffic. For a short time it appeared that the use of a light coating of oil or tar on the surface would preserve the road, but as motor vehicles increased it became more evident that the type of surface must be changed.

Various experiments were made with tar, asphalt and other materials, and the so-called bituminous macadam road was evolved and has been satisfactorily used up to the present time, where it has been built with suitable foundation. This type of surface pavement can best be described by taking verbatim the specifications of the State Department of Public Works, which are as follows:

"The base course shall consist of broken local or trap stone spread and rolled on the sub-grade prepared as hereinbefore specified.

"The width of the base course shall be eighteen (18) feet except on banked curves, where the width shall be twenty-one (21) feet, and the depth shall be four (4) inches, unless otherwise specified, after rolling with a steam roller weighing not less than ten (10) tons.

"The broken stone for the base course shall consist of clean, durable, crushed rock having a French coefficient of wear of not less than 8, and shall consist of No. 1 and No. 2 stone. The No. 1 stone shall consist of stone that will pass through a ring two and one-half ($2\frac{1}{2}$) inches in diameter and will not pass through a ring one and one-quarter ($1\frac{1}{4}$) inches in diameter.

"The No. 2 stone shall consist of stone that will pass through a ring one and one-quarter ($1\frac{1}{4}$) inches in diameter, but will not pass through a ring one-half ($\frac{1}{2}$) inch in diameter.

"The proportion of No. 1 and No. 2 stone to be used in the base course shall be as directed by the engineer, the intention being, where stone is crushed locally, to vary the proportions in order to use the output of the crusher.

"The course shall be shaped to a true section conforming to the proposed cross-section of the highway, and when thoroughly rolled shall be two (2) inches below and parallel to the proposed finished surface of the surfacing course.

"Any depressions or irregularities which may occur shall be filled with broken stone, of such sizes as directed by the engineer, and again rolled until the surface is true and unyielding. The interstices in this course shall then be filled with stone screenings, and after being thoroughly rolled the screenings shall be just below the top of the broken stone as directed by the engineer, and no screenings shall be left on top of the stones.

"All broken stone shall be spread from carts by hand, or from a dumping board, or from self-spreading carts which shall be of a type approved by the engineer.

"If so ordered by the engineer the thickness of the broken stone shall be increased or diminished at such points as he may direct.

"The finished surface of the road shall present such a crown as shall be directed by the engineer.

"If local stone or stone not shipped by rail is used it shall be weighed on scales furnished by and at the expense of the contractor. Said scales shall be satisfactory to the engineer, and they shall be sealed at the expense of the contractor as often as the engineer may deem necessary to insure their accuracy.

"A sworn weigher, to be appointed and compensated by the department, shall weigh all the broken stone required to be weighed as above provided.

"If the stone is shipped by rail the car weights may be accepted, but scales shall be used as above provided if the engineer so directs.

"This work shall be paid for at the contract unit price per ton for broken stone rolled complete in place, which price shall include all materials, equipment, tools, labor and work incidental thereto.

"The bituminous macadam surface shall be laid on a 'broken stone base course' constructed as hereinbefore specified.

"The surface course shall be composed of broken, local or trap stone and bituminous material applied by the penetration method, with the bituminous material covered with pea stone.

"The width of the bituminous macadam surface course shall be eighteen (18) feet, except on banked curves, where the width shall be twenty-one (21) feet.

"The broken stone shall conform to the requirements specified for broken stone base course, and shall consist of No. 1 stone, excepting for covering the bituminous material, for which pea stone shall be used.

"Pea stone shall consist of that portion of the crusher product which will pass a three-quarter ($\frac{3}{4}$) inch screen and will be retained on a quarter inch screen and shall be free from dust.

"Upon the 'broken stone base course,' shall be spread an upper course of No. 1 stone, which shall be two (2) inches in depth after rolling with a steam roller weighing not less than ten (10) tons.

"The upper course shall be shaped to a true section conforming to the proposed cross-section of the highway, and when thoroughly rolled shall conform to the proposed grade and cross-section.

"Any depressions or irregularities which may occur shall be filled with broken stone, of such sizes as directed by the engineer, and again rolled until the surface is true and unyielding.

"Upon the upper course of stone, prepared as hereinbefore described, bituminous material shall be uniformly applied by a pressure machine at the rate of one and three-quarters ($1\frac{3}{4}$) gallons to each square yard of surface and uniformly covered with clean pea stone in sufficient quantity to fill the surface voids and permit the steam roller to pass over it without sticking to the bitumen. Brooms shall then be used in spreading this first coating of pea stone. The surface shall then be thoroughly rolled, and after rolling, the surplus pea stone and dust shall be completely removed by sweeping.

"A second application of bitumen shall then be made in the same manner as in the first application, so as to completely coat the surface, and shall be at the rate of one-half ($\frac{1}{2}$) gallon per square yard. After the second application of bitumen has been made, it shall be uniformly covered with a sufficient coating of pea stone, as directed by the engineer, and then thoroughly rolled.

"The bitumen when applied to the upper course of stone shall have a temperature approximating 300° F. for oil asphalt or 200° F. for refined tar.

"Any depressions or irregularities appearing after the final rolling shall be neatly patched in such a manner as shall be directed by the engineer, so that the final surface shall be perfectly uniform and true to the specified cross-section and grade.

"If at any time before the acceptance of the work any soft or imperfect places or spots shall develop in the surface, all such places shall be removed and replaced with new material and then rolled until thoroughly compacted, and until the joints or edges at which the new work connects with the old become invisible. All such removal and replacing of unsatisfactory surfacing shall be done at the expense of the contractor.

"No bituminous work shall be done during rainy weather, nor when weather conditions as to temperature or otherwise are, in the opinion of the engineer, unsatisfactory for obtaining good results.

"The stone shall be perfectly dry before applying the asphalt.

"The contractor shall not allow the asphalt to be overheated or burnt.

"This work shall be paid for as follows:

"The broken stone shall be paid for at the contract unit price per ton rolled complete in place.

"The bituminous material shall be paid for at the contract unit price per gallon heated and applied complete in place.

"The above prices shall include all materials, equipment, tools, labor and work incidental thereto."

In the earlier construction of this type of pavement, asphalt or tar of too soft a nature was used, with the result that roads of that type show a wavy surface after two or three years' use. This condition can only be corrected by rather extensive scari-fying, reshaping, and the addition of more material of proper quality and consistency.

Practice has shown that the asphalt or tar to be used in this climate should conform with the following specifications, which are sufficiently elastic to let in all good material of the kind specified and yet are sufficiently stringent so that poor material cannot be used. The specifications mentioned are as follows:

"Oil asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

" It shall meet the following requirements:

1. Specific gravity, 25° 25° C. (77° 77° F.)... Not less than 1.000
2. Flash point..... Not less than 175° C. (347° F.)
3. Melting point..... 35° C. (95° F.) to 55° C. (131° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec..... 90 to 120
5. Loss at 163° C. (325° F.), 5 hours..... Not more than 1.0%
 (a) Penetration of residue at 25° C. (77° F.), 100 g., 5 sec.,
 Not less than 60
6. Total bitumen (soluble in carbon disulphide),
 Not less than 99.5%
- Organic matter, insoluble..... Not more than 0.2%

" Fluxed native asphalt shall be homogeneous, free from water, and shall not foam when heated to 175° C. (347° F.).

" It shall meet the following requirements:

1. Specific gravity, 25° 25° C. (77° 77° F.)..... 1.030 to 1.050
2. Flash point..... Not less than 175° C. (347° F.)
3. Melting point..... 40° C. (104° F.) to 50° C. (122° F.)
4. Penetration at 25° C. (77° F.), 100 g., 5 sec..... 90 to 120
5. Loss at 163° C. (325° F.), 5 hours..... Not more than 3.0%
 (a) Penetration of residue at 25° C. (77° F.), 100 g., 5 sec.,
 Not less than 45
6. Total bitumen (soluble in carbon disulphide),
 Not less than 95.0%
- Organic matter, insoluble..... 1.5% to 2.5%

" Refined tar shall be homogeneous and free from water.

It shall meet the following requirements:

1. Specific gravity, 25° 25° C. (77° 77° F.)..... 1.200 to 1.280
2. Float test at 50° C. (122° F.)..... 100 sec. to 150 sec.
3. Total distillate by weight:
 To 170° C. (338° F.)..... Not more than 1.0 per cent.
 To 270° C. (518° F.)..... Not more than 10.0 per cent.
 To 300° C. (572° F.)..... Not more than 20.0 per cent.
 (a) Melting point of residue,
 Not more than 65° C. (149° F.)
- Total bitumen (soluble in carbon disulphide)..... 75% to 88%

During the last few years there has been a great increase in the use of cement concrete as a surface pavement. The first cement concrete section built by the Commonwealth was in the year 1913, in North Andover, and the use of this type of surface

has been gradually increasing from year to year to such an extent that during the year 1921 about one half of the state highway construction was of this type.

The specifications under which the 1921 work was built are as follows:

"The surfacing shall consist of concrete composed by volume of one (1) part of Portland cement, two (2) parts of fine aggregate, and four (4) parts coarse aggregate, constructed on the prepared sub-grade, in one course, and in accordance with these specifications.

"The surfacing shall be twenty (20) feet in width, except on banked curves, where the width shall be twenty-four (24) feet, seven and one-half ($7\frac{1}{2}$) inches in depth at the center, and six (6) inches in depth at the side.

"The top surface shall conform to the arc of a circle, with a crown of two and one-half ($2\frac{1}{2}$) inches at the center.

"The cement used shall meet the requirements of the standard specifications and tests for Portland cement, adopted by the American Society for Testing Materials, September 1, 1916, with all subsequent amendments and additions thereto adopted by said Society.

"Every facility shall be provided the engineer for careful sampling and inspection of the cement, either at the mill or at the site of the work as may be specified by the engineer. At least ten (10) days from the time of sampling shall be allowed for the completion of the seven-day test; and at least thirty-one (31) days shall be allowed for the completion of the twenty-eight (28) day test. The twenty-eight day test shall be waived only when specifically ordered.

"The water used shall be free from oil, acid, alkalies or organic matter, and neither brackish nor salt.

"The fine aggregate shall consist of clean, hard, durable, uncoated particles of sand, preferably of a siliceous nature, free from clays, soft or flaky particles, loam and all organic matter. Where approved by the engineer, a combination of washed or dustless screenings and sand, containing not more than fifty (50) per cent. by volume of screenings, may be used for the fine aggregate.

"The washed or dustless screenings used as fine aggregate shall consist of material obtained by crushing hard, durable rock or gravel and shall be free from clay and other impurities.

"The fine aggregate shall be well graded from coarse to fine, and when tested by means of laboratory screens and sieves shall meet the following requirements:

Passing $\frac{1}{4}$ -in. screen	100%
Passing 20-mesh sieve.....	30% to 75%
Passing 50-mesh sieve.....	Not more than 20%
Passing 100-mesh sieve.....	Not more than 5%

"The fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement and three (3) parts of fine aggregate by weight when made into briquettes will show a tensile strength at seven and twenty-eight days, at least 100 per cent. of that developed, in the same time, by mortar of the same proportions and consistency, made of the same cement and standard Ottawa sand.

"The coarse aggregate shall consist of clean, durable, broken stone, or gravel stone, free from soft, thin, elongated or laminated pieces, disintegrated stone, vegetable or other deleterious matter. The stone shall have a French coefficient of wear not less than eight (8).

"When tested by means of laboratory screens the coarse aggregate shall meet the following requirements:

Passing $2\frac{1}{2}$ -in. screen.....	100%
Passing 2-in. screen.....	Not less than 95%
Passing 1-in. screen.....	30% to 75%
Passing $\frac{1}{4}$ -in. screen.....	Not more than 5%

"The transverse joint filler shall consist of prepared bituminous paving strips of a quality approved by the engineer, one (1) inch wider than the thickness of the surfacing of a length equal to the width of the surfacing, and one-half ($\frac{1}{2}$) inch in thickness.

"The forms shall be of wood or metal, of a width equal to the depth of the concrete, true to line, free from warp and of sufficient strength, when staked, to resist the pressure of the concrete without springing, and so designed that the various sections may be fastened together in such a manner as to prevent vertical or horizontal movement of the ends.

"If of wood, they shall be two (2) inch surfaced plank, not less than twelve (12) feet in length unless otherwise ordered by the engineer. The top of the wooden forms shall be bound with angle irons according to the directions of the engineer.

"If of metal, they shall be of approved section and shall have a flat surface on top of not less than one and three-quarters ($1\frac{3}{4}$) inches.

"The forms shall be joined neatly and tightly, shall be set true to line and grade, well staked and braced, and shall have uniform bearing on the sub-grade throughout their entire length.

In general the setting of forms shall proceed at least two hundred (200) feet in advance of the mixing and placing of concrete. The forms shall be thoroughly cleaned before any concrete is placed against them.

"The forms shall be made tight to prevent the leaking of mortar from the concrete.

"The contractor shall provide sufficient forms so that it will not be necessary to remove them within twelve (12) hours after the concrete is placed.

"The accurate measurement of each of the materials composing and the production of a uniform mixture of the concrete are essential. The contractor shall furnish and use approved timing devices, a water measuring and discharging device, also boxes or pans of such dimensions as will give, when filled and struck, the exact volumes of aggregate required by the engineer.

"The materials shall be mixed wet enough to produce a concrete which will flatten out and quake when deposited in place, but not enough to cause it to flow or the mortar and coarse aggregate to separate.

"The water shall be accurately measured and gaged, and shall be automatically discharged into the drum with the aggregates. The quantity of water shall be determined by the engineer and not varied without his consent.

"Concrete shall not be mixed or placed when the temperature is at or lower than thirty-five (35) degrees F., and no materials containing frost shall be used. Cement or aggregate containing lumps or crusts of hardened material shall not be used.

"The concrete shall be mixed in such quantity as is required for immediate use, and any which has developed initial set or has been mixed longer than forty-five (45) minutes shall not be used. Remixing with additional water, mortar or concrete that has partially hardened will not be permitted.

"In no case shall concrete be deposited upon a frozen sub-grade.

"Concrete shall be mixed thoroughly in a batch mixer of a type approved by the engineer, for a period of not less than one and one-half ($1\frac{1}{2}$) minutes after all the materials are in the drum, and during this period shall make not less than fourteen (14) nor more than twenty (20) revolutions per minute.

"The entire contents shall be removed from the drum before materials are placed therein for the succeeding batch.

"If the mixer is operated on the sub-grade, planks shall be provided for the mixer to run on, so that the sub-grade shall be kept in good condition.

"Concrete shall be placed only on a moist sub-grade. If the sub-grade is dry it shall be sprinkled with as much water as will be readily absorbed.

"The concrete shall be deposited on the sub-grade, between the side forms, rapidly in successive batches, by means of a discharging device which does not cause separation of the mortar and the coarse aggregate, and shall be distributed to the required depth and for the entire width of the surfacing by shoveling or other approved methods. Rakes shall not be used for handling concrete.

"This operation shall be continuous, completing sections between expansion or contraction joints without the use of intermediate forms or bulkheads.

"The cement concrete surfacing shall be reinforced with steel deformed rods, and dowels shall be used as shown on the plans and in accordance with these specifications.

"All reinforcing shall be deformed steel rods with a cross-section area of twenty-five hundredths (0.25) square inches, and not less than eight (8) feet long.

"Dowels shall be deformed steel rods for the longitudinal joints, and plain steel rods for the transverse joints, and shall be two (2) feet long and of the same area as the reinforcing rods.

"The reinforcing rods and dowels shall be placed as shown on the plans and in such manner as to insure their remaining in the desired position during the placing and hardening of the concrete. The dowels for the transverse joints shall be painted one-half ($\frac{1}{2}$) their length with bituminous material of a quality satisfactory to the engineer.

"This work shall be paid for at the contract unit price per pound for all reinforcing steel rods and dowels.

"The above price shall include all materials, all equipment, labor and work incidental thereto.

"Expansion or contraction joints shall be placed sixty feet apart and shall be made vertical, entirely through the concrete and perpendicular to the center line of the surfacing.

"A longitudinal joint shall also be placed in the center line of the concrete surfacing. If only one half of the width of the surfacing is constructed at one time the face of the concrete shall be painted with bituminous material before the other half of **the concrete is placed.**

"The longitudinal joint shall be poured with bituminous material according to the direction of the engineer.

"The bituminous material for painting and filling the longitudinal joint shall meet the following requirements:

1. Specific gravity, 25°/25° C. (77°/77° F.) . . . Not less than 0.980
2. Flash point Not less than 200° C. (392° F.)
3. Melting point Not less than 80° C. (172° F.)

4. Penetration at 25° C. (77° F.), 100 g., 5 sec. 30 to 50
5. Loss at 163° C. (325° F.), 5 hours. Not more than 1.0%
 Penetration of residue at 25° C. (77° F.), 100 g., 5 sec.
 Not less than 20
6. Total bitumen (soluble in carbon disulphide),
 Not less than 99.5%
 (a.) Organic matter insoluble. Not more than 0.2%

" The surface of the concrete shall be struck off by means of a steel template of approved section weighing not less than two hundred (200) pounds for a length of eighteen (18) feet. The template shall be rolled to the desired cross-section and have sufficient strength to retain its shape under all working conditions. This template shall be moved with a longitudinal and crosswise motion, moving always in the direction in which the work is progressing. Care shall be taken in moving the template forward that it is not lifted from the side forms, but shall be held securely against the top of the forms and moved forward uniformly, thus preventing undulations in the surface.

" Immediately after the concrete has been struck off it shall be rolled with an approved metal hand roller having a smooth, even surface, approximately six (6) feet in length, not less than eight (8) nor more than twelve (12) inches in diameter, and weighing not more than one hundred (100) pounds. This roller shall have a handle at least two (2) feet longer than the width of the surfacing, and all the rolling shall be done from one side of the surfacing. The roller shall pass from one edge of the surfacing to the other in one operation, and the rolling shall continue until free water ceases to come to the surface.

" After the rolling has been completed, the concrete shall be finished by using a belt made of canvas or rubber belting not more than twelve (12) inches in width nor less than two (2) feet longer than the width of the surfacing. This belt shall be worked with a longitudinal and cross-wise motion as described for the steel template. Care shall be observed in the use of the belt not to permit the edges to dig into the surface of the concrete or to work the crown out of the surfacing.

" The concrete adjacent to the transverse joint shall be finished with a split wood float which will ensure finishing both sides to the same grade, after which the edges of the concrete at all joints shall be rounded with an approved edging tool to a radius of three-sixteenths ($\frac{3}{16}$) of an inch and the sides of the slabs to a radius of approximately three-quarters ($\frac{3}{4}$) of an inch. The finishing of the joints shall be done from a bridge which shall not rest on the concrete at any point.

"Concrete surface finishing machines of a type approved by the engineer may be used as an alternate method of finishing to that described above.

"Finally, the surfacing shall be lightly broomed with stable brooms.

"As soon as finished, the concrete shall be protected by a canvas covering, suspended not less than twelve (12) inches above the surface, and, if directed, the surface of the pavement shall be sprinkled with water. When the concrete has hardened sufficiently, the canvas covering shall be removed and the entire surface of the pavement wetted thoroughly and covered with earth or other approved material to a depth of not less than two (2) inches. This material shall be kept moist by sprinkling with water, if directed, and shall remain on the concrete for a period of not less than ten (10) days under the most favorable conditions, or for a longer period if directed by the engineer, during which time traffic shall be excluded from the concrete by the erection and maintenance of suitable barricades, and satisfactory precautions shall be taken to exclude foot traffic for a period of not less than three (3) days. When required or approved, other methods of curing and protecting the concrete may be used.

"After the foregoing period has elapsed, the covering on the concrete shall be removed, the surface of the pavement swept clean and the concrete allowed to cure for a period of three (3) days, after which the roadway may be opened to traffic.

"This work shall be paid for at the contract unit price per cubic yard for 'cement concrete surfacing' complete in place, which price shall include all concrete and contraction or expansion and longitudinal joint materials, all forms, equipment, tools, labor, including rolling, belting, protection of concrete, wetting and work incidental thereto."

It must not be inferred that bituminous macadam and cement concrete are the only types built by the Commonwealth. Practically every known type of surface appears somewhere in the state highway system, but the prevailing surfaces are of the above-mentioned types.

Proper foundation and drainage have always been looked upon by highway engineers as the most essential requirements for a suitable highway, but they have never been more essential than at present, when loads as heavy as locomotives of a half century ago are permitted to use the highways. The question is sometimes asked, "How thick must the foundation be under a cement concrete road?" and this question is sometimes asked by

engineers who are very competent in their special line of endeavor. No definite answer can be given to such a question, particularly in this state, where the geological formation is so widely variable. In no section of the state is there a road where the subsoil conditions are uniform for a distance of one mile. There are many miles where no foundation whatever is necessary under a suburban highway pavement, while on the other hand there are many miles where foundation 12 ins. to 18 ins. in depth is absolutely necessary.

There are also many miles where no serious attention has to be given to surface drainage or sub-drainage, whereas on the other hand there are many miles where both deep side ditches and under-drains are necessary, and where if these are omitted the pavements will become partially destroyed, necessitating considerable expense for maintenance, particularly after the frost has left the ground in the spring.

Material of two types is generally used by the state for foundation, the first being a coarse, sandy gravel, the second, broken cobbles of variable dimensions up to approximately 10 ins.

In connection with this necessity for adequate foundation it may be well to call further attention to the weights of loads now passing over highways. In 1917 the loading of trucks was increased to such an extent that it appeared that there must be some check to the weights that could be permitted on the highways. The legislature of that year enacted a law limiting the net weight of all vehicles with loads to 14 tons, and with the further restriction that the load on any tire should not exceed 800 lbs. to the inch width.

During the past two years, and particularly in 1921, the Department of Public Works has employed an investigator to ascertain what loads were being carried over the highways and to prosecute the law-breakers as he found them. The extent to which this law has been ignored is remarkable. He found that trucks having a rated capacity of 5 tons and weighing approximately 5 tons were carrying loads weighing from 10 to 15 tons, so that the total load of truck and vehicle was approximately from 15 to 20 tons, and with the worn-out tires on many of the trucks, the load per inch width of tire was approximately

from 1 000 to 1 500 lbs. Statistics under preparation by the department will show that this overloading is not confined to isolated cases, but is very frequent, and must be considered not only in connection with road surfaces and foundations but in connection with the designing of bridges.

The cost of road construction to-day averages about six times greater than that of thirty years ago. Several conditions have led to this increase. In the old days of horse-drawn vehicles, a road surface 15 ft. wide was considered adequate on all suburban roads, and in many cases a surface 12 ft. wide was sufficient. The same roads to-day need surfaces at least 18 ft. wide, and in many instances 24 ft. The minimum width constructed anywhere to-day is 15 ft. On main through lines of travel where the number of vehicles per day is sometimes as high as 3 000, the width should be at least 20 ft. with a sufficient width of suitable shoulder to make an aggregate available width in emergencies of 26 ft.

On the road between Worcester and Springfield a large amount of reconstruction has been carried on during the present year, and the width, in this case, of hardened surface has been made 20 ft., with the foundation carried out 3 ft. on each side to permit future further widening without great expense.

Another reason for the increased cost is the necessity for improved permanent surfaces, and still another is the necessity for more adequate foundation. Where in 1895 a water-bound macadam might be built for approximately \$6 000 per mile, a cement concrete or other equally strong surface and suitable foundation cost in 1921 about \$40 000 per mile. In 1921 a fair average cost of a bituminous macadam surface 18 ft. wide, consisting of 4½-in. base course and a 2½-in. penetrated upper course, exclusive of all expense except the construction of pavement above the foundation, was about \$3.00 per sq. yd. The cost of reinforced cement concrete surface as compared with the above is about \$3.05 per sq. yd. It is, however, gratifying to those who are interested in getting as much highway as possible constructed each year to observe that the costs of construction gradually decreased during the year 1921, and the outlook is that with this decrease in cost and with the increased use of

machinery, the expense of road construction in 1922 will probably be less than it has been for several years.

In connection with the state construction in Massachusetts, a few words of explanation of the federal aid for road construction may be of interest.

In the year 1916 Congress passed an Act making an appropriation of \$75 000 000, a small percentage of which sum was set aside for road construction in the national forests, and another small sum for maintenance of the Bureau of Public Roads in Washington, and the remainder being divided in the states of the Union, one third in the ratio which the area of each state bears to the total area of all the states; one third in the ratio which the population of each state bears to the total population of all the states; and one third in the ratio which the mileage of rural delivery routes and star routes in each state bears to the total mileage of rural delivery routes and star routes in all the states.

Massachusetts under this apportionment receives about 1.6 per cent. of the funds distributed, which, under the Act of 1916, amounted to \$1 105 765.23. This appropriation covered three years.

In 1919 a second appropriation was made of \$200 000 000, the share of Massachusetts being \$2 946 799.87. A third appropriation has just been made, amounting to \$75 000 000, the Massachusetts share being \$1 096 176.04.

The proportion of the cost of a road that the Federal Government will pay is 50 per cent. up to a maximum of \$20 000 per mile, with an added 50 per cent. of the cost of any bridge over 20 ft. span included in that project. For example, if a state project is one mile long and contains also a bridge over 20 ft. span, the cost of building the road being \$42 000 and the cost of building the bridge being \$20 000, the amount the Federal Government would pay, according to this expense, would be \$20 000 toward the road and \$10 000 toward the bridge.

A condition under which this money is distributed is that the state guarantee to maintain the road after construction. This necessitates laying out of all such roads as state highway before or immediately after their completion; otherwise the state could not make any guaranty.

DISCUSSION.

MR. JOHN R. RABLIN.* — I did not prepare any paper for this discussion, although I was requested to do so, but knowing that Mr. Dean's paper would thoroughly cover the subject I thought it would be tedious for you to hear another paper, although it certainly was not to hear his.

I will say a few words about the work with which I have been connected during the last twenty years, and discuss a few points which occur to me after reading over Mr. Dean's paper.

The Metropolitan Park system, as planned, provided for the acquirement of several woods and shore reservations, connected by parkways. The construction of these parkways was begun in 1895, but no large amount of work was done until about 1898 or 1899. Contrary to the state highway practice at that time, the parkway roads were built of ample width, so that since then we have seldom had occasion to widen the roads. They were laid out and constructed from 26 to 36 ft. in width, as parkways, or "boulevards," as they are commonly known. Some were even as wide as 40 ft. There have been some cases where they were not originally constructed to the full width planned, as the traffic did not require it at that time, but they were laid out with the intention of widening them when traffic demanded it. They were constructed generally with either gravel or water-bound macadam surface. Many were built of gravel, and it is remarkable how some of those gravel roads have stood up even to the present time. Roads constructed with a gravel surface, under our specifications in 1899, are in use to-day by the present automobile traffic, and some of them are in very good condition, merely being surface-treated with asphaltic oil. Many of them, on the other hand, haven't stood up at all. It depends on the quality of gravel used. Of course the fact must be borne in mind that all heavy traffic is excluded from the park roads and only light traffic, such as pleasure vehicles, allowed, and when they were built the reason for making them of gravel was that the light carriages which used them — many of them

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rubber-tired — didn't require macadam. It is quite remarkable that so many of those roads have lasted to this time, because if now we should build a gravel road with asphaltic oil surfacing, it probably would not stand a week. I don't know what the explanation is, unless it is that the old roads had become thoroughly compacted by use before treatment.

Regarding the subject of wavy surfaces, it appeared that some of these gravel roads after several applications of the oil became saturated to such a depth that we had a surface of fine aggregate filled with a fairly soft asphaltic oil, which was unstable under automobile traffic. We also found that our water-bound macadam roads — which were generally constructed with a 4-in. bottom course of No. 1 stone and 2 ins. of No. 2 stone on top, bound with stone dust — when later treated with asphaltic oil became a soft plastic mass and waved very badly. Our later type of construction, when it became necessary to build the bituminous macadam roads, which we now build exclusively, calls for a 6-in. depth of No. 1 stone with the voids near the surface filled with pea stone and No. 2 stone, and thoroughly rolled. Then the bituminous binder is applied. That is somewhat different from the Public Works Department's specifications, described in Mr. Dean's paper, but their depth of stone is greater than ours. We get a very good, compact surface with one 6-in. course, well rolled. By having the No. 1 stone — the larger stone — at the surface bound together with asphalt or tar binder, the tendency to bunch up and roll up and wave is eliminated.

With reference to gravel and water-bound macadam surfaces, some of the original costs are interesting. I looked up some of the old costs of our department recently, and found bids received for gravel surface which called for 5- to 6-in. depth of approved gravel, ranging from 15c. to 50c. per square yard. They were built for from 15 to 25c.; and bids for water-bound macadam from 30 to 57c., generally built for less than 50c. per square yard.

On our re-surfacing of old macadam and gravel roads, which has become necessary in many instances since the automobile traffic developed, we have used from 3 to 5 ins. additional stone, and have constructed by the same specifications as in new construction.

The bituminous macadam costs in our work have ranged in 1915 and 1916 from 60c. to 90c. per sq. yd., including binder; in 1919, from \$1 to \$1.50 per sq. yd., including binder; and in 1921, from \$1.50 to \$3.50. Those are bids. The work has actually cost in the last two years from \$1 to \$1.50. That cost is for the surface only, and does not include grading, drainage or anything else.

Statements of the cost per mile of constructing various types of road are of little value for comparison, because, as Mr. Dean explained, they started in the State Highway Commission to build their roads 12 to 15 ft. wide and are now building them 20 to 24 ft. wide. We build ours 26 to 36 ft. wide. The cost per mile doesn't mean anything unless the width of road is given. We have been criticized for having a higher cost per mile of road than that of the state highways, the width not being taken into consideration.

Our re-surfacing costs for bituminous macadam in 1915 were from 60c. to \$1, and in 1919 from \$1.10 to \$1.50, in 1920 from \$1 to \$1.60 per sq. yd. Now we estimate about \$1.50 on the average for re-surfacing with bituminous macadam on existing roadways. It costs more to re-surface a gravel road than a macadam road because we get the benefit of some of the stone in the old macadam roads.

In the acquirement of the park system, certain existing roads were taken over. These must be built and maintained for heavy traffic, mixed traffic, all kinds of traffic, and we usually lay on those roads what we consider a better type of pavement than we would lay on the strictly park road. This class of road is similar to the state highways. On these, we have used bituminous concrete pavements and Portland cement concrete pavements. With reference to bituminous concrete pavements, Mr. Dean didn't mention that type in his paper. I don't know whether he purposely omitted it or not. I refer to a class of so-called "patented pavements" such as the Bitulithic, Warrenite, Topeka, Bitoslag, Unionite, National, etc. All are more or less of the sheet asphalt type and are laid either on a concrete base or upon a macadam base. We have recently tried the experiment of laying a few short stretches of these surfaces on old macadam

bases, and at the present time they are standing up very well. Using a 2-in. top we have laid sections of Warrenite, Topeka and Bitoslag. The Bitoslag is built by substantially the same specification as the others, merely substituting slag for the crushed stone.

In the Portland cement concrete pavement the specification read by Mr. Dean, providing for the reinforcement, referred to the plans showing just where and how it should be placed. I think there is still, and has been for some time, some question as to just where and just how much reinforcement to put in the concrete road surfacing, — whether it shall all be placed at the top, all at the bottom, or in both places. The stresses, of course, in a concrete road are somewhat different from those in a slab floor or roof, and I am not prepared to say just where or how much reinforcement ought to be used. In fact, perhaps some of you may remember that a year or two ago a gentleman talked to us here about concrete pavements, and made the statement that you should use as much reinforcement as you had money to spend for it. That was, of course, somewhat indefinite — he intimated none was needed. I think, however, since then most engineers and experts on road construction have come to the point where they approve of reinforcement in the concrete roads. Although it does not entirely prevent cracking, it probably lessens it considerably and holds the pavement on a true plane. After it has cracked, one section doesn't rise above the other or settle below the next.

I think it is only quite recently that the longitudinal joint has been used to any extent, in the construction of concrete road surfaces, and it is my opinion that it is quite necessary, as the longitudinal crack which almost invariably appears is more unsightly than the transverse crack. Generally, especially if the pavement is reinforced, there is no injury to the pavement because it cracks. It is merely unsightly, and if filled with pitch or asphalt causes little damage to the pavement.

There are still other types of cement concrete pavement. There is a Portland cement concrete pavement which I think is controlled by patents, — at least a certain part of the work is, I understand, — the Hassam pavement, in which the stone is

laid as in the ordinary macadam pavement and grouted with cement grout and rolled as it is grouted. The claim is that the wear comes upon the stone directly, and not upon the film of cement mortar which covers the stone in a mixed concrete.

Recently, there has been brought to my attention another type which is called "Soilamies." If this pavement proves all that is claimed for it, it is expected that it will reduce the cost of cement concrete pavements from 30 to 40 per cent. Briefly, the specification is — and its name comes from this fact — that any soil that is found in the subgrade may be used for aggregate. They expect to excavate the road surface to subgrade and use the excavated material to mix with their cement and a secret ingredient which allows any soil, whatever it may be, to be used as the aggregate. There have been some experimental sections of this laid — mostly in Pennsylvania, I believe. As to its merits, of course we only know what we have been told.

In the matter of foundations, one point occurred to me which I thought might be of interest to you, — that we have found, where we have a clay subgrade, that if we lay crushed stone or a coarse gravel over it, before laying our macadam, in a few years, if we have occasion to excavate, most of the stone seems to have disappeared and the clay to have come to the surface or mixed with the stone. This action is probably due to frost and moisture. We have also found that by covering the clay with a layer of fine sand before putting on the coarse gravel or stone, it will prevent that to a large extent.

The question is asked as to how the Hassam pavement compares in cost, life and wearing qualities with the type of pavement that Mr. Dean specifies.

I think I can hardly answer that, not having had the experience with the use of this pavement a sufficient length of time. The cost at the time we built a section about two years ago was less than the cost of the ordinary concrete specification under that contract.

There is one thing that I do not approve about the "Hassam" specifications, and that is that they omit joints, either longitudinal or transverse. The pavement cracks, as all concrete pavement does, and of course the cracks are irregular in all

directions. It seems to me that joints could be provided in that type as well as in the other. It might be more difficult, but I think it could be done, and should be done. You can provide for expansion and contraction joints in the mixed concrete, and I think you could in this.

As to its wearing qualities, I couldn't give an opinion on that at the present time.

MR. HENRY V. MACKSEY.*—I have been very much interested in Mr. Dean's paper. It seems to me that we should pay more attention to the elimination of dangerous places on highways. I can readily understand the attitude taken by the Public Works Department of the Commonwealth in building roads, because it never has money enough to do all that it would like to do. It is forced, as we are in little towns, to make as many miles as possible with the amount of money available; but it does seem that changes might be made in the policy of the Commonwealth. It now contributes out of its funds to the construction of gravel roads. There never was a rule made that will not admit of an exception, and I am willing to admit that in the very small, poor towns, where a decent highway is needed in order to provide for through traffic, it is well to give money to help build gravel roads; but in a town that has a considerable traffic itself and has means and money, the state should not contribute toward building gravel roads. The towns should take care of their own gravel roads and the state should help them to build permanent roads.

In laying out state highways, where old roads are to be improved, almost always the old road is taken as it is and slightly improved. At a railroad grade crossing we do not separate the grades. It is just as important to separate grades where a highway meets a railway as to separate grades where two railways meet. A collision between a train and a jitney carrying forty people may mean little to the railway, but it may mean forty lives.

In regard to the different types of pavements, we really haven't had modern concrete pavements in this section long enough to know just how they compare with others in durability,

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but I think the whole story will be told by the foundation which supports the pavement. Pavement, after all, is but a covering. If you reinforce a concrete pavement and the frost heaves up the edges, you may have sufficient reinforcement to hold the pavement up as a beam without cracking. If you have a bituminous pavement it will crack under such conditions but will cement itself together again, which concrete pavement will not do. There is not a great difference in cost between the two, but it is an open question whether we should always prefer cement concrete. As Mr. Larned said, there are many times conditions other than durability to be considered. For instance, a question recently came before the board I work with. They were asked by a Finance Committee to put cement concrete pavement on one of the main roads of the town, which is not built up at all on one side and only slightly on the other. There is a good prospect of building operations very shortly, and in the near future we would have to lay a sewer, and would cut the pavement for that the entire length of the street, and also for water services, gas services, sewer connections and water connections. In making cuts the difference in cost is not great if you have kept clear of that infernal reinforcement. But the cost and inconveniences are considerable, as it takes two weeks to season concrete so that you can allow traffic over it, whereas with bituminous pavement we allow traffic on it within an hour. I have been surprised to find that in the last year or two the policy of the Massachusetts Highway Department has apparently changed. Five or six years ago it was strongly in favor of the hot mix — bituminous pavement — and it laid a great deal of such pavement. It was very good, has lasted well, and most of it has not waved. Of course some was poor, because that class of pavement requires not only good material but expert workmen and inspectors, which were not always provided. It is very difficult for the Massachusetts Highway Department to always take the best contractor from among the bidders. It cannot, like a private party, turn down a man because it thinks he will not do good work. He is the low bidder, shows his bond and agrees to work according to specifications. Reliable inspectors are hard to get. The younger men just out of college

have not had enough experience to tell them when they can put their foot down and hold it down, and when they can't. Many times they will make too much of a trifling matter and let the large one pass. There are many stages of the work which need to be watched in a mixed concrete job, whether it is bituminous or Portland cement. One of the commissioners of the Massachusetts Highway Department has stated that to lay concrete right they needed four inspectors, but they never have that many.

There is considerable virtue in bituminous pavements, and I am surprised that bituminous concrete is not laid now by the State Department.

The bituminous penetration type is the ideal pavement for a little town to build. It can be built with less plant and less skilled labor than any other durable pavement, but it does require surface treatment for maintenance. You must seal it frequently. You will get a better pavement by using nothing but No. 1 stone, or even larger. It is a stone road, and bitumen used only to hold the stone in place. Why not stones as large as can be held together? I believe that a change should be made in the state specifications, eliminating the smaller sizes, even though the cost be greater.

A. P. PORTER.* Before an engineer can design a structure, or any part of a structure, it is necessary for him to know three things: first, what loads it is to carry; second, what stresses these loads will cause, and, third, what materials will resist these stresses.

In the design of pavements the highway engineer has concerned himself principally with the third consideration, what materials to use. The last year has seen the first determined attempts to solve the second question; witness the experimental road in Pittsburg, Calif., and the tests conducted by the Bureau of Public Roads at Washington. At the present time much attention is being paid to the first-mentioned consideration, namely, the loads coming upon the highways.

The speaker can give some first-hand information on the subject of loads, because, for the past two summers, he has been

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employed by the Massachusetts Department of Public Works, under Commissioner John N. Cole, investigating the heavy loads imposed on the highways by motor trucks.

We started to weigh the trucks with two loadometers. The loadometer is a device on the screw-jack principle, with an oil gage attached to give the weight. The two instruments are first placed under the rear axle, screwed up until the wheels are off the ground and the readings taken. Then this process is repeated with the front axle. The sum of the four readings gives the total weight of truck and load.

In using the loadometers, I found it is wise to choose a spot where the roadway is nearly level in both directions, for if one of the jacks stands on the sloping shoulder of the road, the side thrust will cause the screw to bind, and not only work very hard but may affect the readings.

During 1920, 90 trucks were weighed by the loadometers, and in 1921 100 trucks by the loadometer and 400 on platform scales.

The first two jacks which I used were calibrated to 20 000 lbs. each, but the second pair, supposed to be an improved model, have a capacity of only 15 000 lbs. each.

The first truck I met after I began using these improved jacks was too heavy to be weighed with them and I had to resort to a neighboring 20-ton platform scale. The rear axle of this truck weighed 33 200 lbs., the heaviest axle load I ever weighed.

The largest gross weight of a four-wheeled truck and load which we actually weighed was 38 300 lbs., and the largest load on six wheels was 40 000 lbs. The accompanying diagrams (Figs. 1 and 2) show the maximum loads we encountered. Undoubtedly there were some larger than these which did not happen to come our way.

Fig. 3 shows all loads over 24 000 lbs. plotted so as to show the total weight, and also the weight on the rear axle for each truck. This latter data will be of interest to the engineer who designs short-span bridges and floor systems.

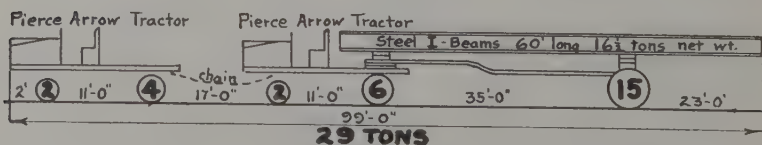
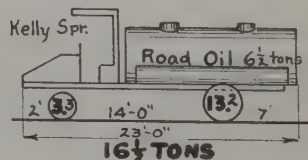
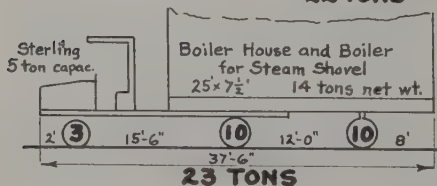
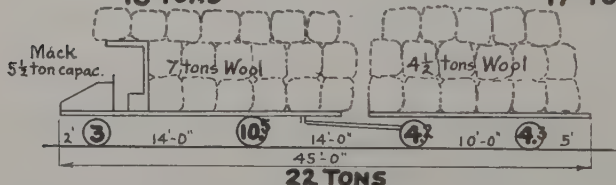
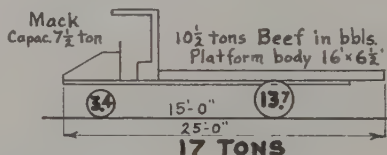
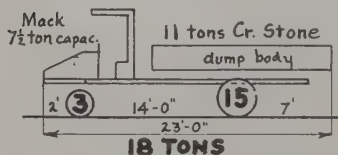
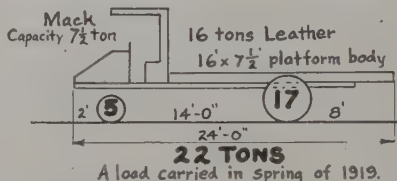
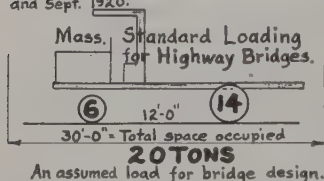
The proportion of the weight which comes on the rear axle of a truck varies from 70 to 87 per cent. It is not constant for a certain truck. As more load is added, the percentage on the rear increases.

Diagrams of Maximum Loadings

Load includes weight of truck and load and is given in thousands of pounds per wheel (tons per axle).

Distance c. to c. of rear wheels averages 6'-0".

All these trucks, except the first two, represent actual loads on Mass. roads in Aug. and Sept. 1920.



not drawn to scale

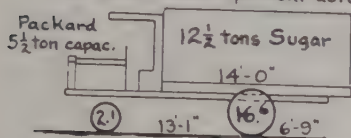
FIG. I — MAXIMUM LOADS ON MASSACHUSETTS HIGHWAYS.

Maximum Loadings 1921

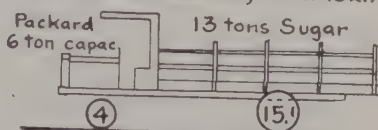
Load includes weight of truck and load and is given in thousands of pounds per wheel (tons per axle).

Distance c. to c. of rear wheels averages 6'-0".

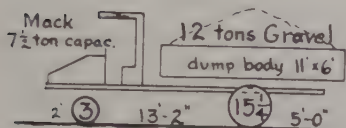
All these trucks represent actual loads on Mass. roads July to Oct. 1921.



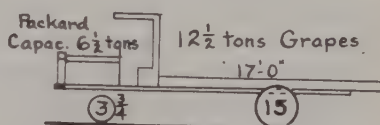
18 ³/₄ TONS



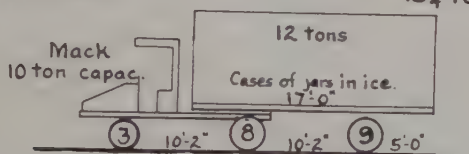
19 ¹/₁₀ TONS



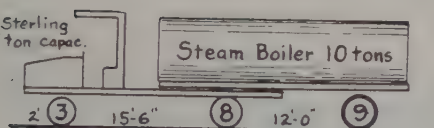
18 ¹/₄ TONS



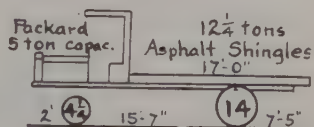
18 ³/₄ TONS



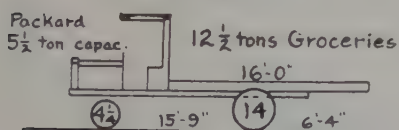
20 TONS



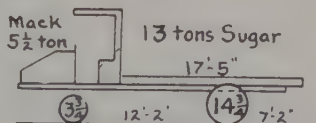
20 TONS



18 ¹/₄ TONS



18 ¹/₄ TONS



18 ¹/₂ TONS

not drawn to scale

FIG. 2 — MAXIMUM LOADS ON MASSACHUSETTS HIGHWAYS.

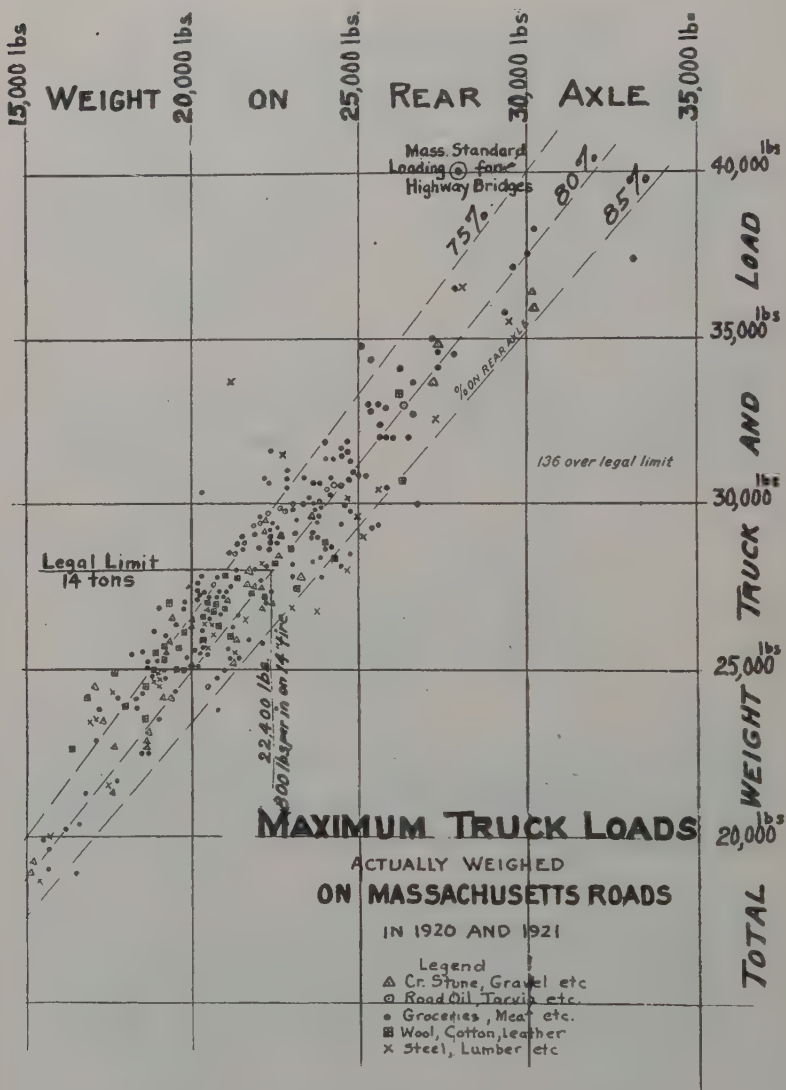


FIG. 3.

It varies also with different makes of truck, different classes of commodities, length of wheel base, length of body, overhang, and how the load is placed. The Autocar has more of its load on the front. Loads of wool or cotton are sometimes piled forward over the cab. The average per cent. on the rear, for all makes, is about 78.

The legal limit in Massachusetts for the weight of truck and load is 14 tons, and outside the Metropolitan Parks and Sewerage districts there is also a limit of 800 lbs. per inch width of tire. Since the largest tire practicable is 14 ins. wide or its equivalent, two 7-in. tires, this practically limits the legal axle load to 22 400 lbs. even with the largest tires.

When the weight of the truck and load was over the legal limit several hundred pounds or more, we summoned the driver to court. So far this year we have had 116 cases in court and secured a verdict of guilty in 109 cases.

Sometimes we made the truckman remove part of his load. On one occasion in Reading, I stopped a truck going from Boston to Lowell which weighed 38 300 lbs., and another owned by the same company going to Lawrence which weighed 34 100 lbs. When told they could not proceed, they telephoned to Boston for another truck, which came out and took 25 barrels of sugar off of one truck and 17 off of the other, which made this third truck overweight.

When we started the investigation there were three facts we wanted to determine:

1. *The Maximum Load.* — Actual weight of heaviest truck load and how its weight is distributed on the wheels. This is to be used as a basis for computing the greatest stresses in the pavement and in bridges.

2. *Overloaded Trucks.* — The ratio of the actual load to the manufacturers' rated carrying capacity is called the "load factor." While we found some trucks carrying as much as two or three times the rated capacity, the average load factor for all the trucks carrying any load is about 1, and taking into account the trucks returning empty the average load factor is about 0.5.

3. *Intensity of Traffic.* — A highway engineer is often called upon to compare the traffic over one road with that over another. For this purpose it is necessary to stop every heavy truck passing a certain point, ask the driver a number of questions regarding the weight of his truck and load, and find the total weight of all the trucks in a given period of time. I adopted "tons-per-hour" as being probably the most convenient unit to express the volume of traffic. For instance, if one road carries ten times as many tons per hour as another, it is reasonable to suppose that the former road will wear out about ten times as fast as the latter and cost ten times as much to keep up, other things being equal.

The diagram entitled "Intensity of Truck Traffic" (Fig. 4) shows first the average weight in tons per hour of the commodities carried: i.e., the pay load; and secondly, the average gross weight of the trucks and loads passing that point, including the weight of the trucks returning empty. The former is an index of the relative economic value of the road to the community. The latter is a measure of the relative wear due to trucks. Pleasure vehicles and light trucks are not included in this diagram.

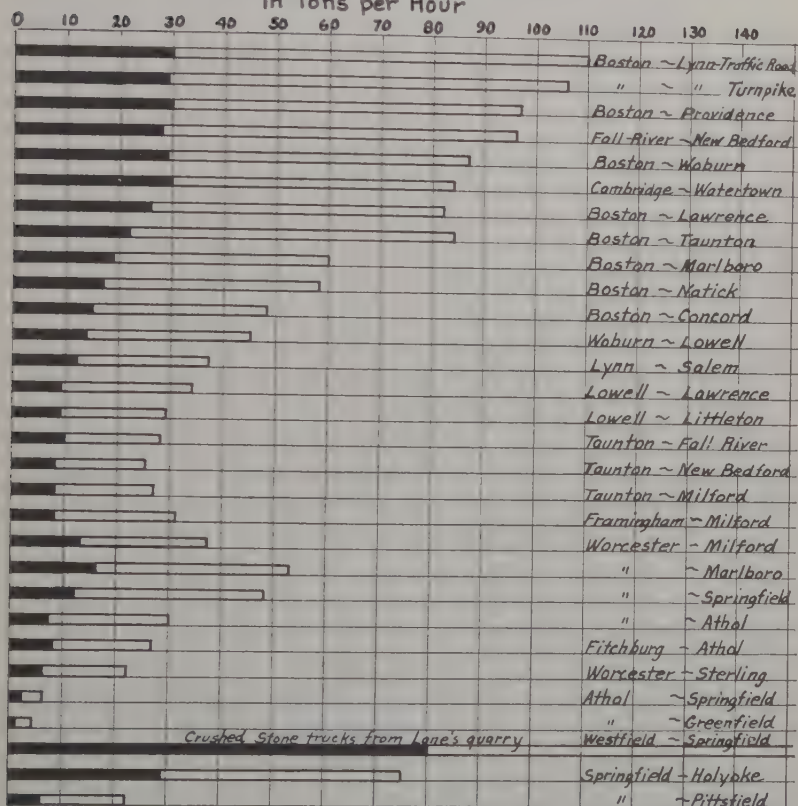
We divided the commodities carried into five groups:

1. Crushed stone, gravel, etc.
2. Oil, gasoline and tarvia in tank bodies.
3. Groceries, meat and drinks.
4. Wool, cotton and dry goods.
5. Machinery, lumber and furniture.

Our analysis of these figures shows some interesting conclusions; among others, that the loads going out from the city are very much greater than the loads going in toward the center. About 75 per cent of the net load on any one of the through routes is going out from Boston, and only 25 per cent coming in. If these could be more nearly balanced, the efficiency of this kind of transportation would be very much increased.

In regard to the effect of the heavy trucks on the roads, it seems to me it is the arch action between the particles of broken stone in the road surface that crushes them. The vertical pressure would not be sufficient.

Intensity of Truck Traffic on Massachusetts roads in Tons per Hour



- Indicates average total net weight in tons per hour, of commodities.
- Indicates " " tare " " " " " " trucks carrying, loads and returning empty.
- □ Combined indicate average gross weight in tons per hour of truck traffic.

FIG. 4.

Suppose there is a little settlement in the soil underneath. The pieces of broken stone form a flat arch which will support autos or light trucks, but under the very heavy truck loads, eight tons or more on one wheel, the horizontal thrust becomes enormous and the arch breaks down. It has been found in excavating old roads that stone near the top surface had become pulverized.

Something was said about a comparison between concrete and bituminous macadam. On Beacon Street, at Chestnut Hill Reservoir, there is a stretch of macadam between two stretches of concrete. The concrete is badly cracked, due apparently to the subsoil sliding toward the reservoir, but the macadam is smooth. As some one said, when macadam cracks, it sticks together again. This quality would indicate its use in cases where there is a possibility of unequal settlement.

MR. DEAN. — I am only going to speak about two minutes. Mr. Rablin spoke about the location and amount of reinforcement in a concrete road. Any bridge designer or building designer will find some way of determining when a portion of a structure is in stress and when it is in strain, and how much the stress and strain is. They can then determine how much reinforcement to use and where to put it. Part of the time steel reinforcement in a road surface is in tension, when the frost is coming out of the ground or in the ground, and part of the time it is in compression. Frost doesn't seem to act twice the same way at the same point. We proved this at North Andover on a road which we called a demonstration road, and not an experimental road. We found that at the same point where one year frost would thrust the road up 6 ins. on one side the following year that point would be down. At another time the same point would be only up 3 ins., the other side up and the center down, or the center up and the other side down. Consequently, the slab is sometimes a beam and sometimes a cantilever. The only way we can effectively reinforce an 8-in. slab on a roadway is to make it practically all steel, or to make it strong enough to hold up the road when only supported on one side or the other.

The main object, in my mind, in using steel is to prevent cracks that result from the heaving action of frost, and to prevent the cracks from growing if once formed.

I might state in answer to what Mr. Rablin has said concerning many of the park boulevards of gravel, with just an oil or tar coating on top, that a year ago last spring, on one of the state highways where the road had been built with from 6 to 8 ins. of broken stone on a good foundation, there was one place where thirteen trucks were mired within a mile and had to be pulled out, which to my mind demonstrates conclusively that the truck is the real menace to the road today and in the future. The ordinary pleasure vehicle, while it is injurious to the old type of road, is not nearly as injurious to the new type as is the heavy motor truck.

With reference to some remarks by Mr. Larned concerning bituminous macadam, I must defend myself and my remarks from misinterpretation. Mr. Larned is probably familiar with the state highway through Wayland and Sudbury that has been built of bituminous macadam, — the first section about ten years ago. It has cost in the vicinity of $1\frac{1}{2}$ c. per square yard per year for maintenance of that surface, and it has cost practically the same amount for the maintenance of cement concrete surfaces. We have many miles of bituminous macadam down six to eight years, in which the maintenance has not been in excess of 1c. per square yard per year, and with that experience (with the actual costs separated from the costs of the other portions of the road — the shoulders, etc.), we feel perfectly justified in building a first-class bituminous macadam road. My belief is that with these trucks, these conditions, the situation is the same as with the railroads. We have got to have sufficient ballast under the railroad track if we are going to carry big locomotives and sufficient foundation under the road surface if we are going to carry 20-ton trucks. I don't think that the surface, — judging from my observations, — provided you get a good, well-built surface, is nearly as important as what you put under the surface and how much you put under the surface. If a bituminous macadam road will stand up for ten years at $\frac{1}{2}$ c. per sq. yd. per year, it seems to me that it has demonstrated that its use is warranted.

I recently had occasion to look up some cost figures, and got the average cost for a 7-in. surface, — $4\frac{1}{2}$ ins. of broken stone base

and $2\frac{1}{2}$ ins. of top. It costs \$2.50 per sq. yd. for that 7 ins. And cement concrete with reinforcement costs about \$3 per sq. yd. at present contract prices. So the concrete surface costs about 50c. per sq. yd. more than bituminous macadam.

I do not wish to give the impression that I do not approve of cement concrete surface, for I do approve of it and believe we should build more.

Mr. Dorr inquires about the economic phase of the truck problem. I think that is a condition we have got to meet to a certain extent. I don't think that the public is expected to build roads for carrying carload lots over the highways, but for ordinary loads, and I think our present law, that limits the load to 14 tons including the vehicle, is about as high as we should go in permitting trucks and merchandise to go over the highways. We do not and should not, in my opinion, attempt in any way to curb the use of the highways for commercial vehicle purposes, but should curb commercial vehicles from attempting to carry 20 or 30 tons over the highway. We have got to have the railroads for long-distance traffic, and I don't think they should be put out of existence as the state railways have been, in order to permit trucks to carry extremely heavy loads — carload lots — over the highways.

It is considerable of a question whether those heavy loads are economical or not. That is being experimented on, — whether it is more economical to carry heavy loads long distances (50 or 75 miles) or to carry moderate loads. It is still indeterminate. The method of using trams on the highways has been used and tried, but my observation has been that where they have been tried they have not been continued long. They have been tried for short distances, but where they have been tried they have not extended those trams any further. So it would appear that they had not been found an economical construction. It is very difficult to construct a tram in a highway and not have the highway break down where the tram rail joins the highway surface, just as it is very difficult to keep the pavement up alongside a street railway track. It is always breaking down there. Granite block is constantly working up and down.

I have not had occasion to treat the surface of our concrete roads, to which reference has been made, in but one or two instances. In both of these instances they were treated because the concrete itself had become bad. It was not properly constructed when built. California roads that were going to pieces have been mentioned. In California several years ago they issued 50 million dollars' worth of bonds and built roads 4 ins. thick. Experience has demonstrated those were not the proper roads for their conditions. I do not know any surface treatment that can be given to any cement concrete road that will not be expensive to maintain. Whether you use asphalt or tar, it will wear off unevenly and can only be made even by very careful hand work. I don't think it is going to be practical to treat the surface of a concrete road with anything less than $1\frac{1}{2}$ ins. in thickness. I do think perhaps a light oil may be used as a dust layer, but it will have to be very light and will have to be applied quite frequently, and of course is objectionable and makes always a dirty surface.

Mr. Macksey asks if for ordinary traffic a 6-in. Portland cement concrete surface, not reinforced, is as safe a proposition as a 6-in. bitumen macadam surface.

This depends very largely upon the traffic and upon the foundation. If you have good, dry, gravel subsoil, 6-in. macadam or 6-in. cement concrete without reinforcement will probably last a great many years, and then can be strengthened by $1\frac{1}{2}$ or 2 ins. of bituminous mixture; 6-in. bituminous macadam under certain conditions might need a little more foundation than would the 6-in. concrete, in order to make it a little stronger. There is not very much choice between 6-in. cement concrete without reinforcement and 6-in. macadam. We have quite a number of miles of both.

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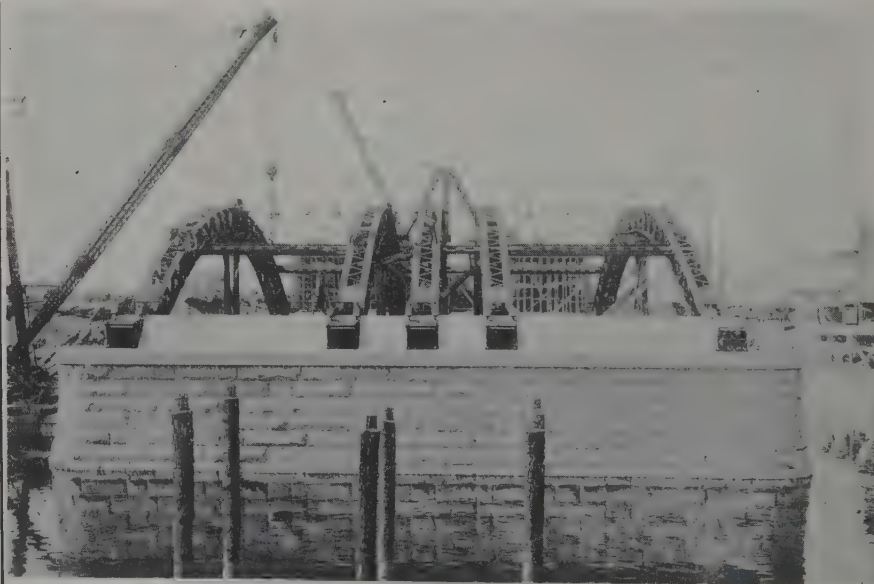
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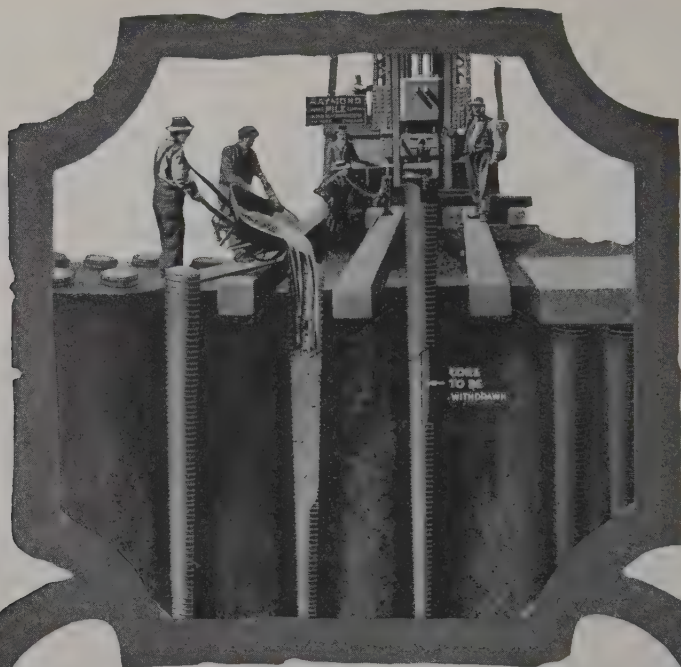
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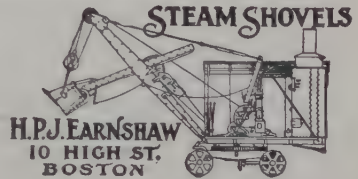
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